FIGURE 1

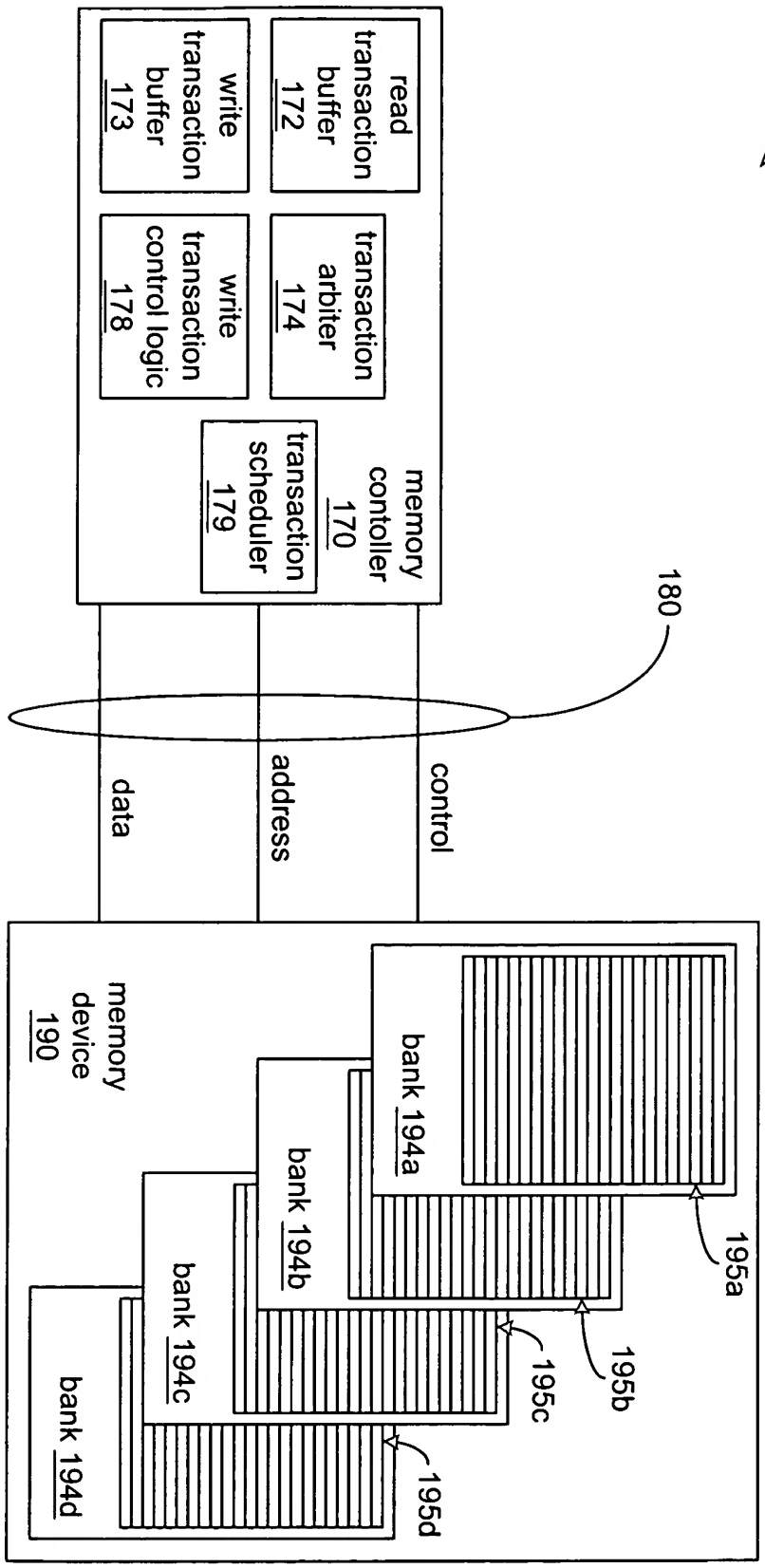

100
memory contoller 170
read transaction buffer 172
write transaction buffer 173
transaction arbiter 174
write transaction control logic 178
transaction scheduler 179
180
data
address
control
memory device 190
bank 194a
bank 194b
bank 194c
bank 194d
195a
195b
195c
195d

FIGURE 2

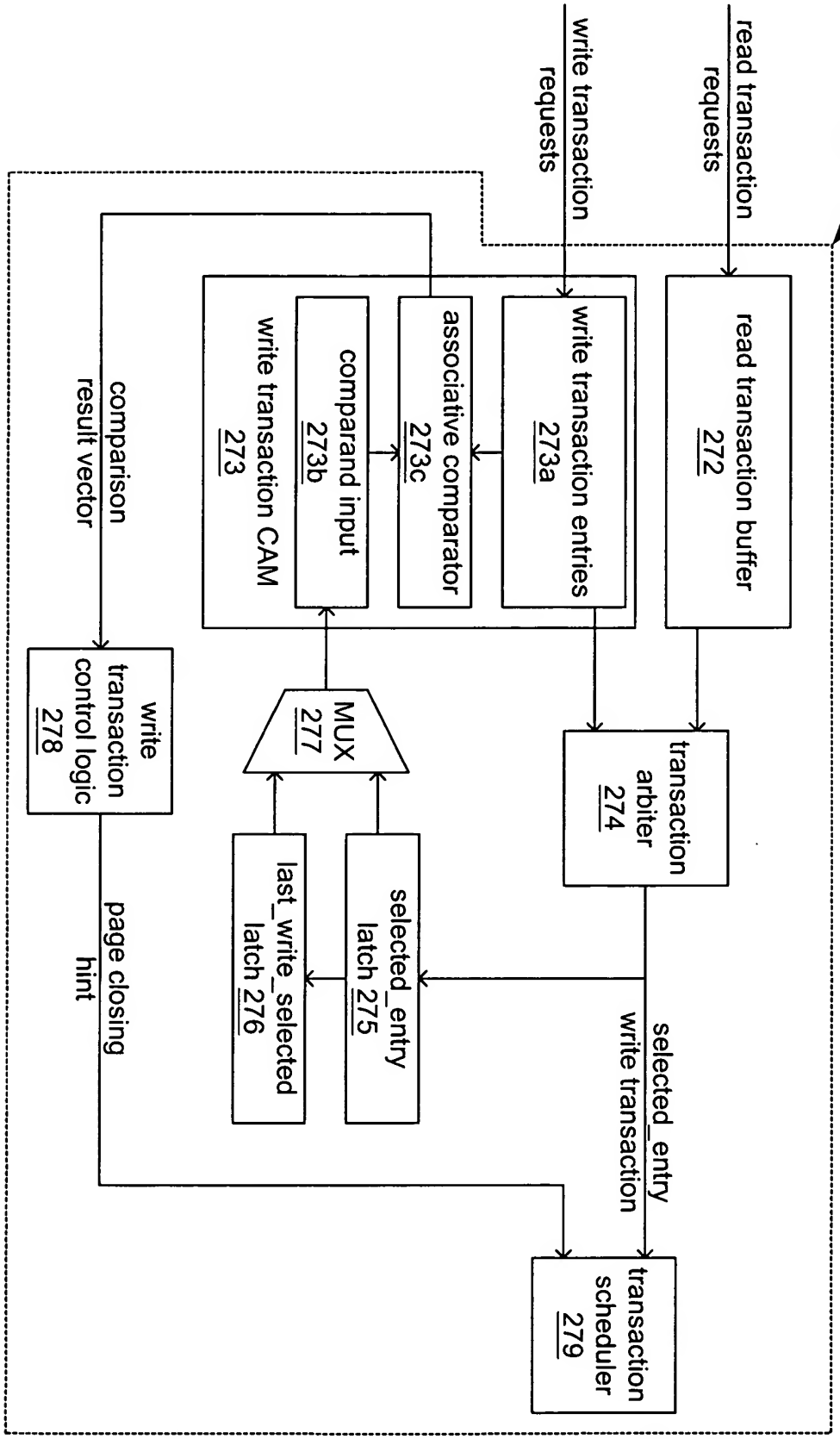

200
read transaction requests
write transaction requests
read transaction buffer 272
write transaction entries 273a
associative comparator 273c
comparand input 273b
write transaction CAM 273
comparison result vector
MUX 277
write transaction control logic 278
transaction arbiter 274
last_write_selected latch 276
selected_entry latch 275
selected_entry write transaction
page closing hint
transaction scheduler 279

FIGURE 3a

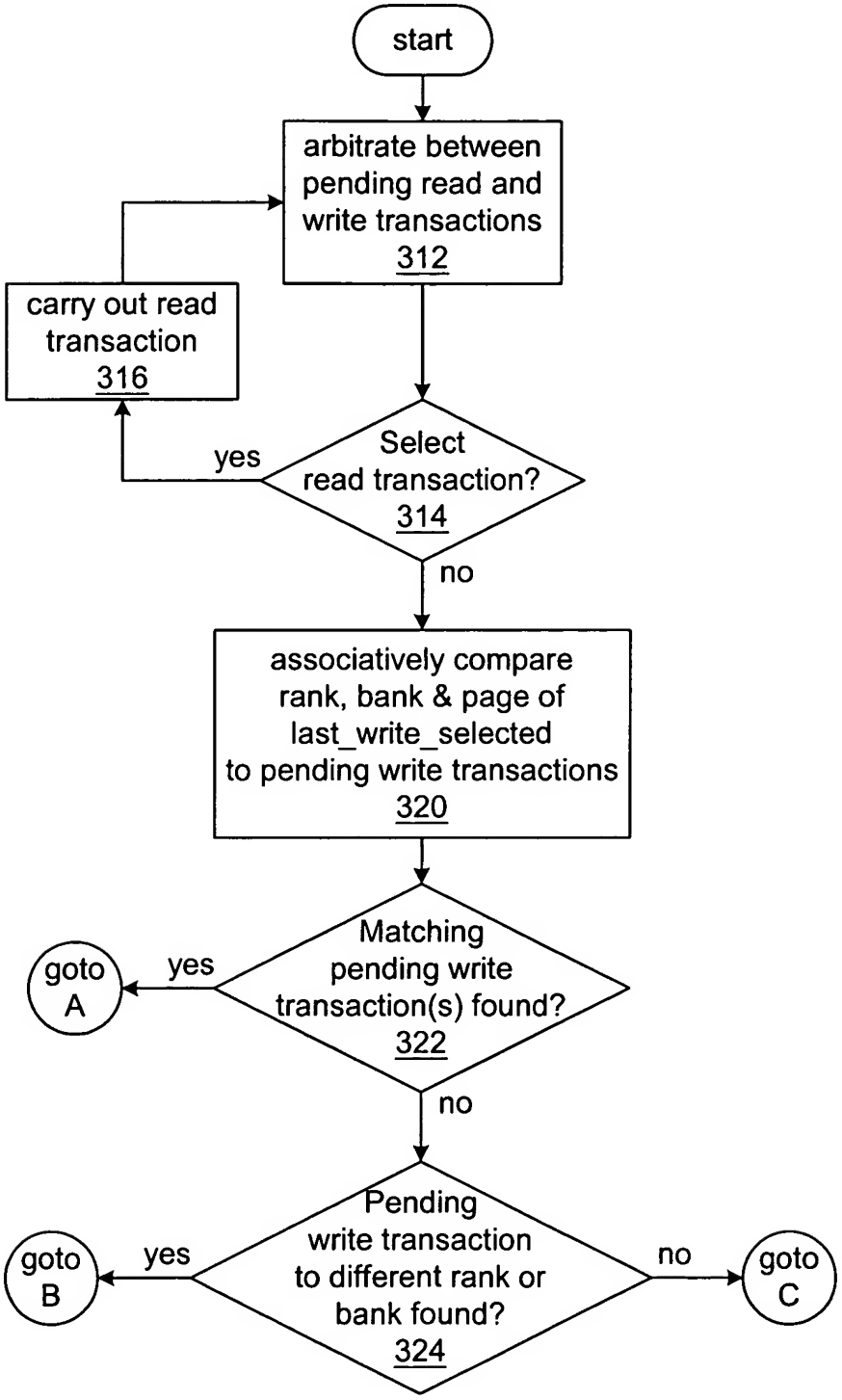

start
arbitrate between pending read and write transactions 312
carry out read transaction 316
Select read transaction? 314
yes
no
associatively compare rank, bank & page of last_write_selected to pending write transactions 320
Matching pending write transaction(s) found? 322
goto A
yes
no
Pending write transaction to different rank or bank found? 324
goto B
yes
no
goto C

FIGURE 3b

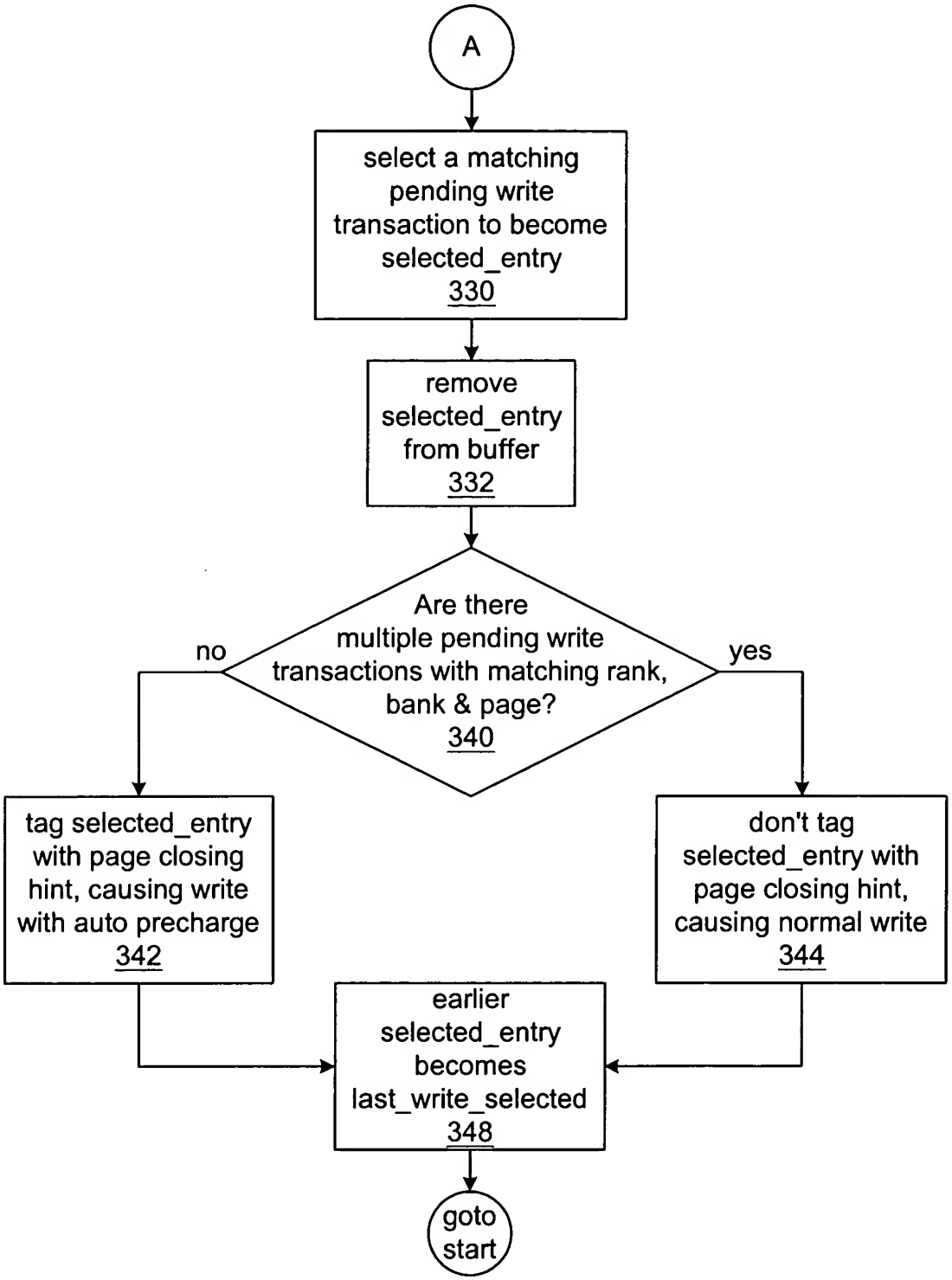

A
select a matching pending write transaction to become selected_entry
330
remove selected_entry from buffer
332
Are there multiple pending write transactions with matching rank, bank & page?
340
no
yes
tag selected_entry with page closing hint, causing write with auto precharge
342
don't tag selected_entry with page closing hint, causing normal write
344
earlier selected_entry becomes last_write_selected
348
goto start

FIGURE 3c

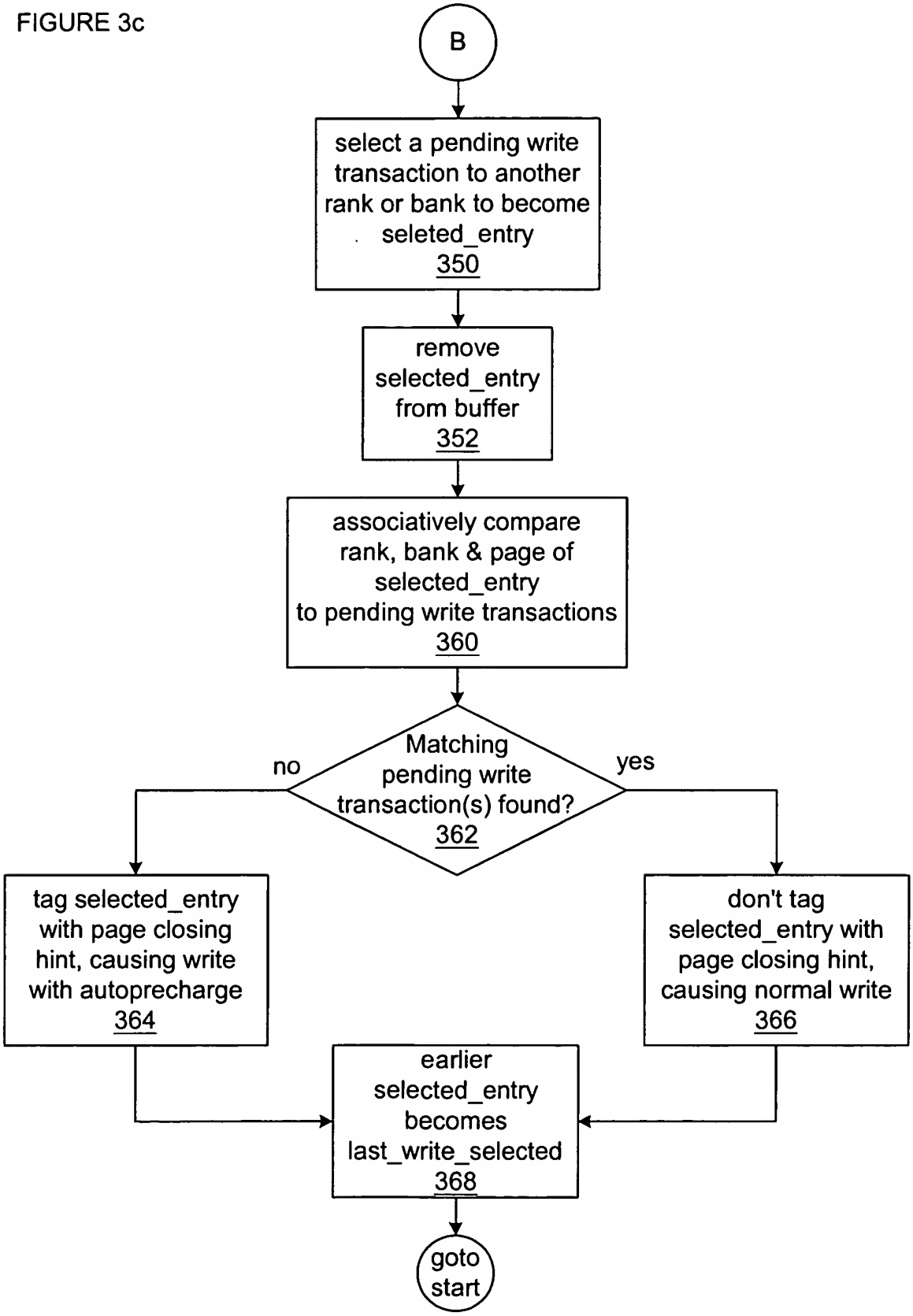

B
select a pending write transaction to another rank or bank to become seleted_entry
350
remove selected_entry from buffer
352
associatively compare rank, bank & page of selected_entry to pending write transactions
360
Matching pending write transaction(s) found?
362
no
yes
tag selected_entry with page closing hint, causing write with autoprecharge
364
don't tag selected_entry with page closing hint, causing normal write
366
earlier selected_entry becomes last_write_selected
368
goto start

FIGURE 3d

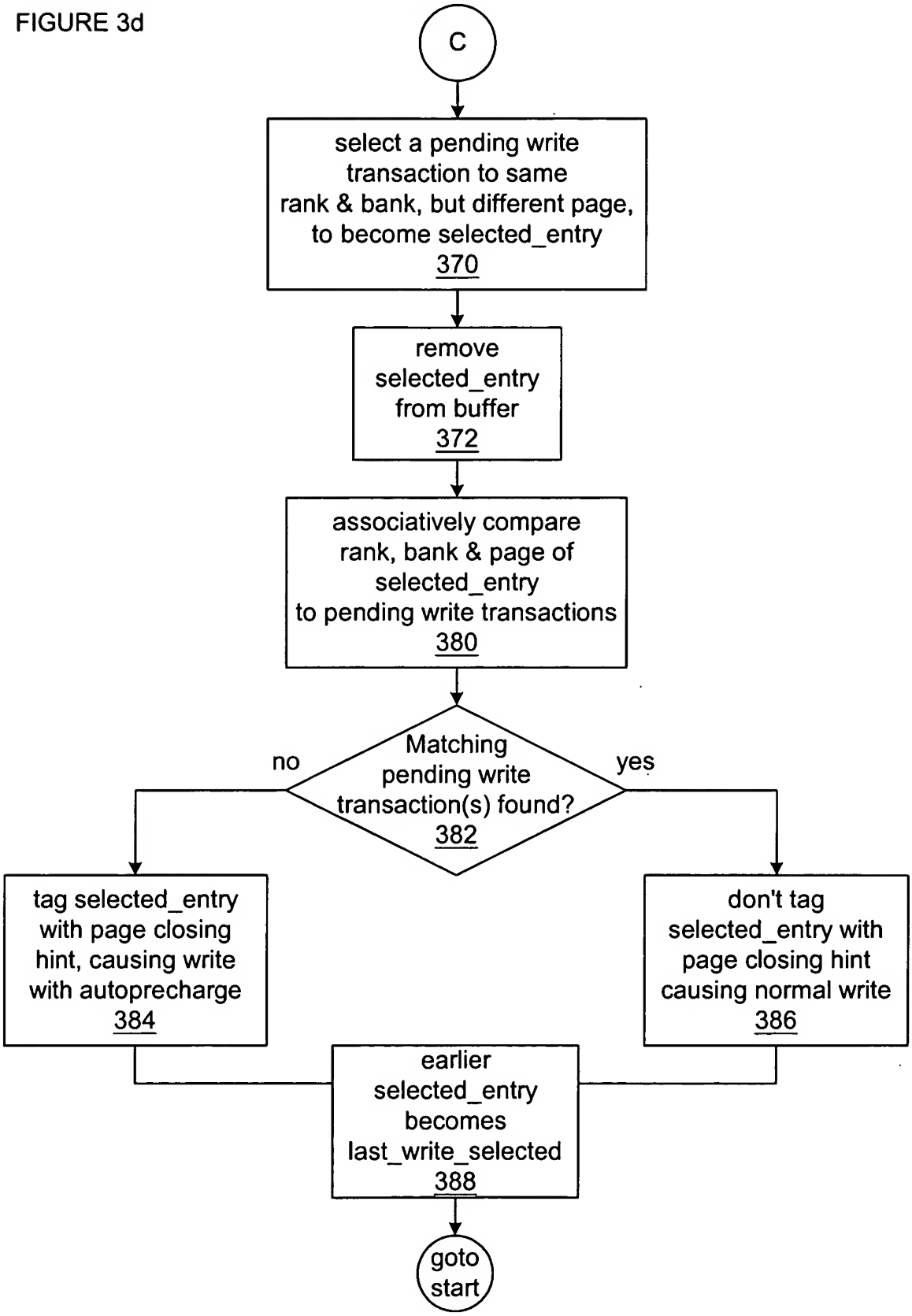

C
select a pending write transaction to same rank & bank, but different page, to become selected_entry
370
remove selected_entry from buffer
372
associatively compare rank, bank & page of selected_entry to pending write transactions
380
Matching pending write transaction(s) found?
382
no
yes
tag selected_entry with page closing hint, causing write with autoprecharge
384
don't tag selected_entry with page closing hint causing normal write
386
earlier selected_entry becomes last_write_selected
388
goto start

FIGURE 4a

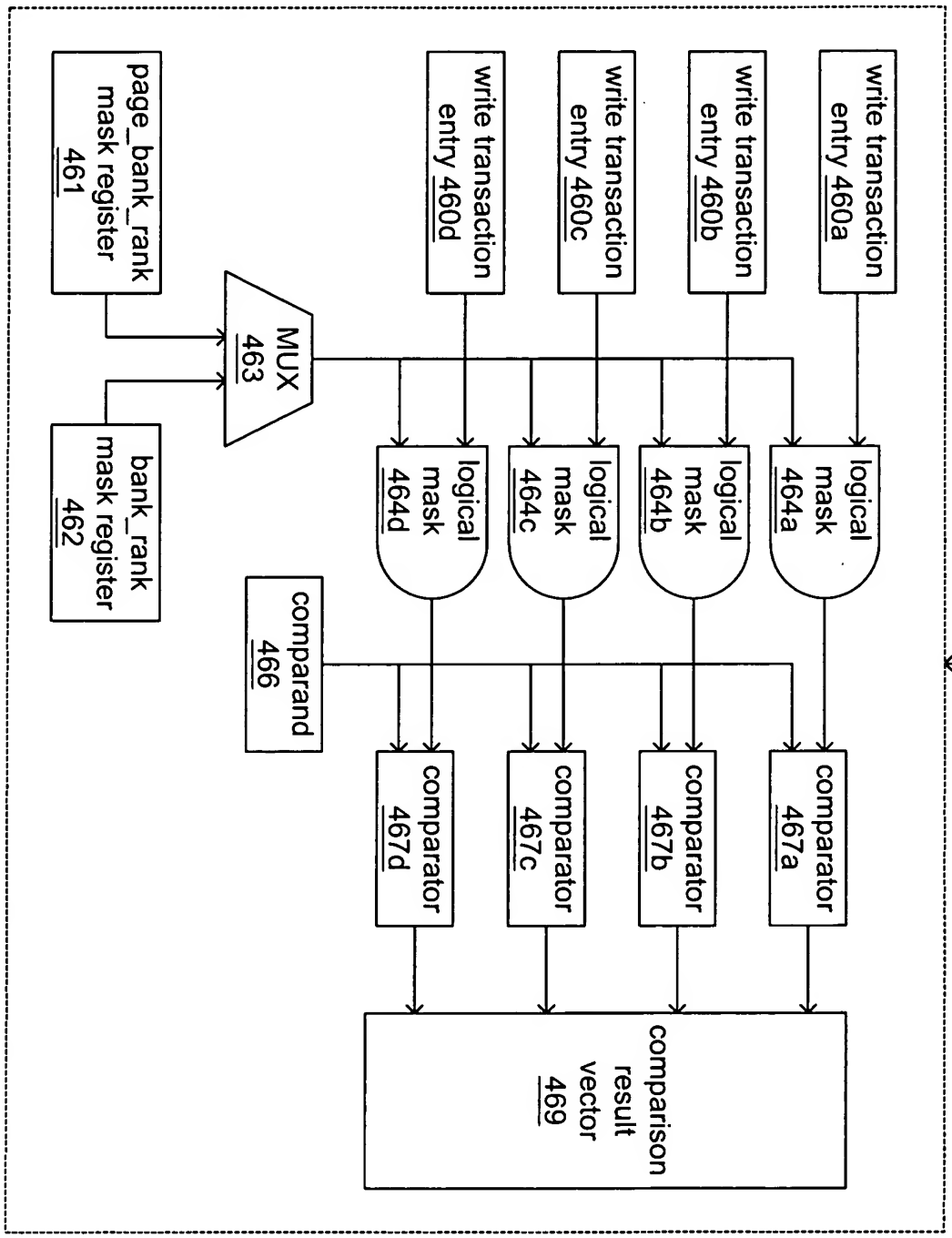
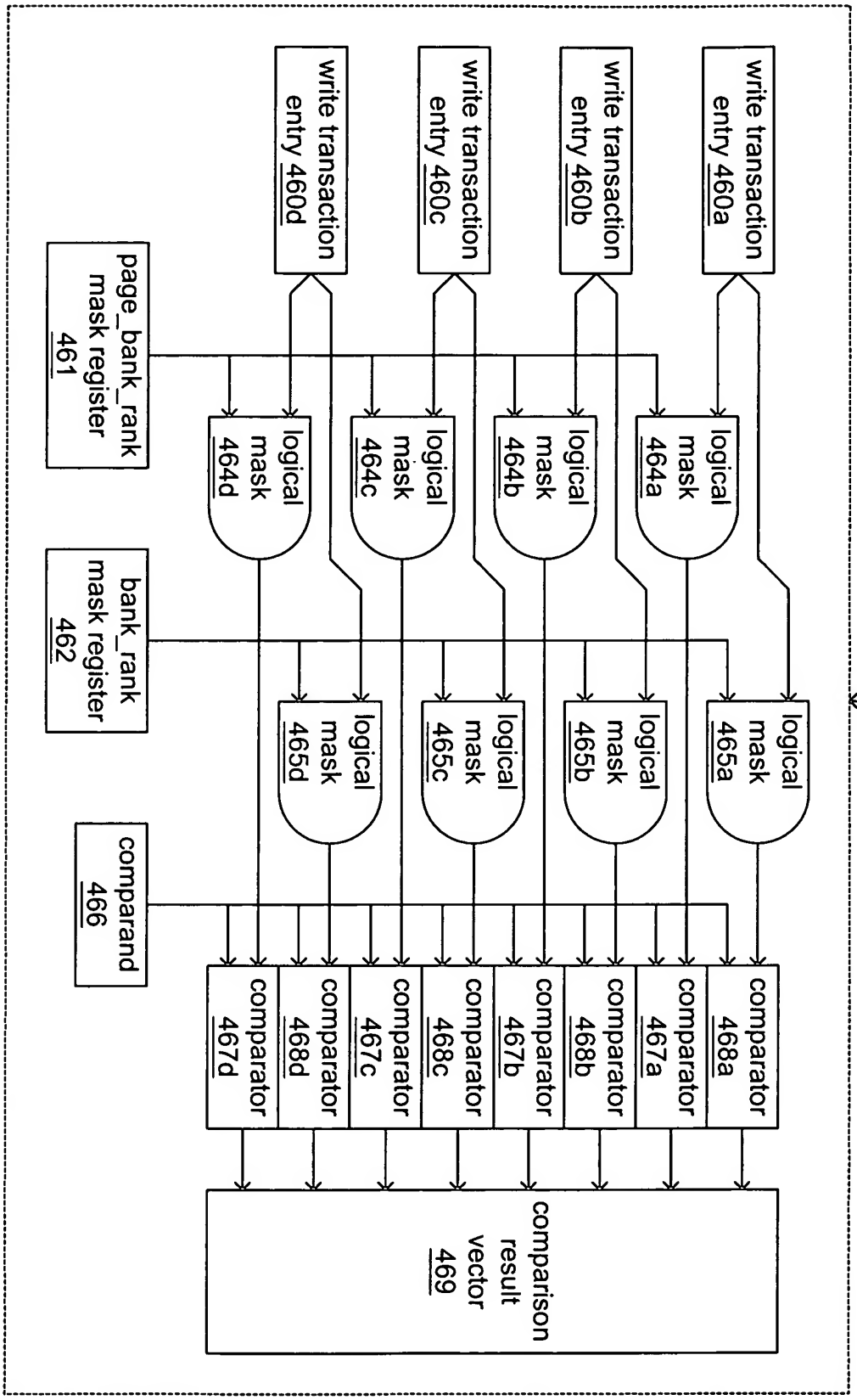

write transaction entry 460a
write transaction entry 460b
write transaction entry 460c
write transaction entry 460d
page_bank_rank mask register 461
bank_rank mask register 462
MUX 463
logical mask 464a
logical mask 464b
logical mask 464c
logical mask 464d
comparand 466
comparator 467a
comparator 467b
comparator 467c
comparator 467d
comparison result vector 469
400

FIGURE 4b


write transaction entry 460a
write transaction entry 460b
write transaction entry 460c
write transaction entry 460d
page_bank_rank mask register 461
bank_rank mask register 462
comparand 466
logical mask 464a
logical mask 464b
logical mask 464c
logical mask 464d
logical mask 465a
logical mask 465b
logical mask 465c
logical mask 465d
comparator 468a
comparator 468b
comparator 467a
comparator 467b
comparator 468c
comparator 467c
comparator 468d
comparator 467d
comparison result vector 469
400

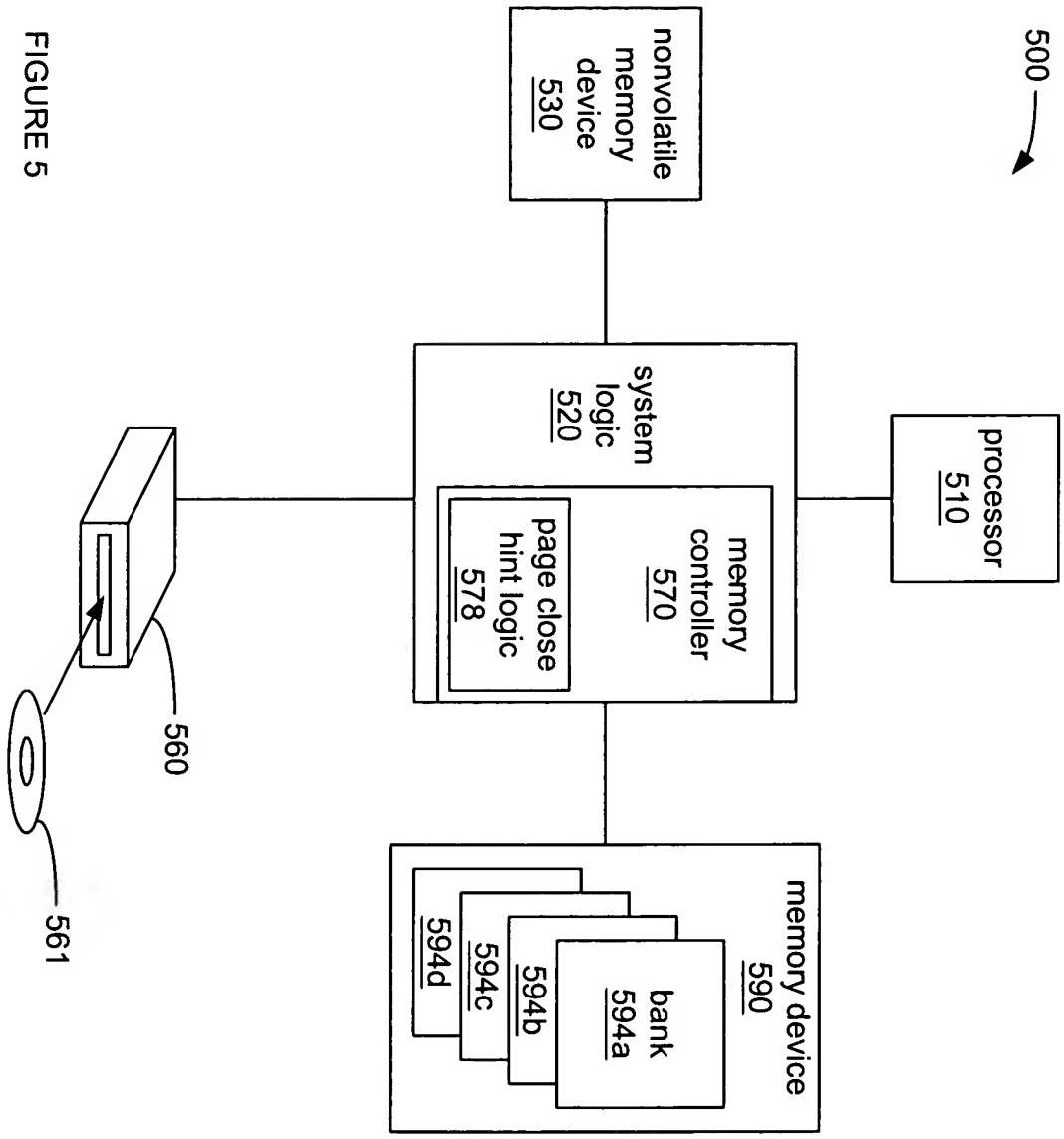

500
nonvolatile memory device 530
system logic 520
memory controller 570
page close hint logic 578
processor 510
560
561
memory device 590
bank 594a
594b
594c
594d

FIGURE 5

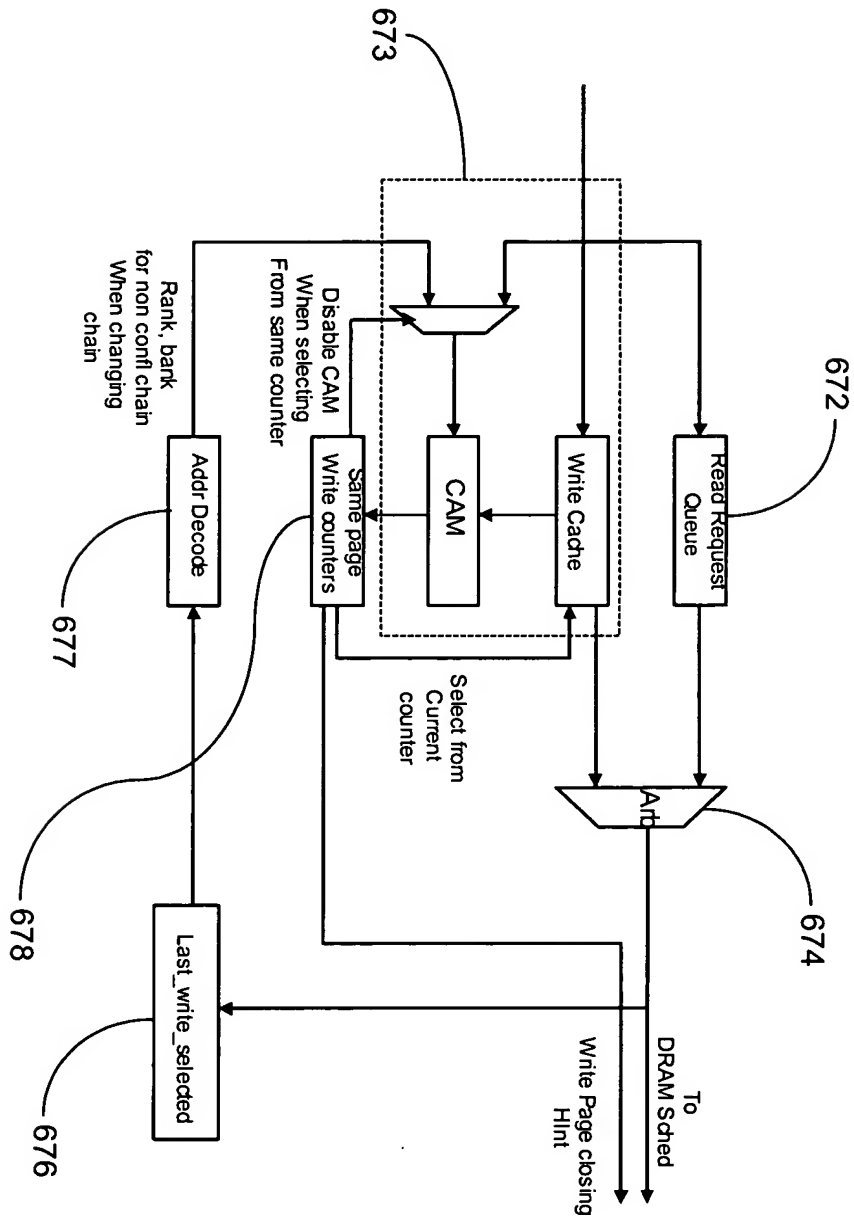

673
672
Read Request Queue
Write Cache
CAM
Same page Write counters
Addr Decode
Rank, bank for non confi chain When changing chain
Disable CAM When selecting From same counter
677
678
Select from Current counter
Arb
674
Last_write_selected
676
Write Page closing Hint
To DRAM Sched

FIGURE 6